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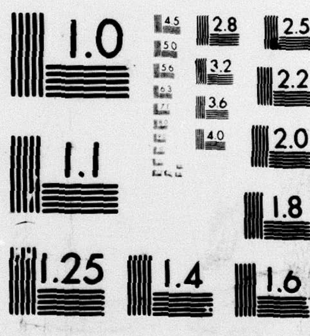

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Methods of reducing the risk connected with operation of radio communication systems in a military environment were investigated. Two alternative approaches were pursued. The first involved methods of direct transport of RF power to remote radiators. Fiber optics, millimeter waves, and intercalated graphite as a low loss low weight conductive medium, were investigated. The second approach involved the use of a widely distributed sparse array as a receiver, transmitter and relay. The array method was found particularly appropriate, giving the effect of distributed obscure source difficult to locate. It was shown that the array

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can be physically isolated from users, requires very little power at each of its elements, can be made self-organizing with the help of its uses, and can provide diversity and reliability advantages.

REMOTE AND DISTRIBUTED ELECTROMAGNETIC RADIATORS

FINAL REPORT

by

Fred Haber

November 1979

U.S. Army Research Office
Post Office Box 12211
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Valley Forge Research Center
Moore School of Electrical Engineering
University of Pennsylvania
Philadelphia, Pennsylvania

FINAL REPORT

REMOTE AND DISTRIBUTED ELECTROMAGNETIC RADIATORS

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1. THE PROBLEM

This study was motivated by the need for methods of reducing the risk arising from the use of electromagnetic radiators in a military environment. The danger of exposure at all levels involved in ground operations was of concern: to men in the field using backpack transceivers, to vehicular users, and to men and equipment concentrated at communication centers. Methods were sought which advance some or all of the following:

(1) Allow remoting single-user dedicated antennas and multiple-user shared antennas to distances sufficient to insure safety of personnel and their installations in the event of discovery of the sources of emission;

(2) allow satisfactory communication at lower emission levels than currently required, in order to minimize detectability;

(3) make sources of emission electromagnetically obscure to inhibit localization;

(4) make it difficult to totally disable the system even when emission is detected;

(5) allow for rapid deployment of emitters;

(6) be resistant to interference, intentional or accidental.

Applicable parameters assumed were as follows. Depending on the nature of the user, safe separations were assumed to range from 100m to as high as 10 km. The frequency range of primary interest was the VHF range, though applications at UHF and higher were also considered. RF power levels when radiating omnidirectionally were assumed less than 100 watts.

The study was to be pursued along two lines. The first was to deal with methods for capitalizing on the gain of large self-organizing arrays of randomly distributed elements to reduce power requirements, thereby alleviating the power transport problem. The second study was to deal with methods of efficiently conveying RF power over distances as specified above.

2. SUMMARY OF RESULTS

The large array study was advanced to a point of high confidence in the approach. Greatest attention was given to the use of the array as a transmit-receive relay acting as intermediary between a major communication center and men in the field. With the aid of the field user the array system is self-organizing to form beams on both field user and communications center. The power required at all transmitter outputs, at the communications center, at the array, and at the field transceiver is extremely small, in part because of the array gain. The system can be so designed as to make the field strength emanating from the communications center available to an unauthorized observer below noise level. The array element outputs individually are also small but the system also benefits from (a) the focusing of power only toward the intended receiver resulting only in sidelobe levels elsewhere, and (b) having the signal emanage from a distributed source making it difficult to totally disable the system. In addition, the use of a source comprised of distributed elements has the potential of improved spatial coverage in rough terrain and in urban areas. By dispersing elements widely the probability that a typically deployed receiver is in view of at least some of the array elements can be made significant. System plans in the form of block diagrams were worked out for two kinds of systems: one in which each array element was demodulated to base-band then remodulated for transmission, and a second system which uses up or down conversion at RF.

Focusing is accomplished in these systems by the use of phase shifters. As a consequence the array will be focused in a band around the center frequency. The frequency characteristic of the array depends on the distribution of elements but for a typical distribution extending over about 1 km square the bandwidth is around 300 KHz. Bandwidths can however be made larger by using a frequency dependent focusing scheme. Frequency characteristics were worked out for a wide variety of array geometries. Similarly, the focal areas obtained with the array under various conditions were worked out. All these results were presented in Valley Forge Research Center reports listed in the references and they were also presented at the 22nd Symposium on Circuits and Systems as indicated in the references. Presentations on the methods devised were also presented at CORADCOM, Fort Monmouth, NJ on May 30, 1979, at a workshop at the University of Pennsylvania on April 6, 1979, and at an invited seminar at Stevens Institute of Technology, Hoboken, NJ on November 14, 1979.

Additional work on the array relay is viewed as being required and is the subject of a new proposal in preparation. It is mainly concerned with the effects of multipath and other imperfections in the transmission path, inadvertent and deliberate interference, multiple access, point to multipoint transmission (in effect, to achieve a broadcast mode) and experiment. Several of these topics have received preliminary attention during the course of the present study.

Consideration was also given to the concept of the "singing array", a scheme by which two arrays automatically focus on one another. Because the method did not appear to offer any advantages not obtained by our method it was not further pursued. Because the singing array (and any array which is to be retrodirective) requires a common phase reference to all its elements a method was studied of transmitting such a reference using a modulated light signal over an optical fiber.

Methods of directly transporting energy over the distances required were also pursued. A brief study was made of the use of millimeter waves in a line of sight path and of optical fiber. In the former case the method envisioned would involve RF modulation of a high power millimeter wave carrier. Demodulating the millimeter wave signal would produce the RF signal and dc power to drive an RF power amplifier. In the latter case a similar approach was proposed though a method by which the primary power would be delivered through a protective cladding around the fiber was also proposed. The millimeter wave and optical approaches continue to be subjects of investigation; at the present time the state-of-the-art is not sufficiently advanced to make the methods immediately practical.

Finally, our work included a study of the potential of intercalated graphite for transporting RF power to remote antenna locations. Heretofore, this approach was considered for low loss low weight power transmission. Our work in this study aimed at finding the material properties at frequencies up to 40 MHz. The work was mainly experimental and consisted of impedance measurements performed on pristine and intercalated graphite fiber bundles which were compared to the values expected from a solid round conductor having the same cross-sectional area. The rf resistivity was found to be comparable to that of a solid conductor (a factor of 20 less than the inductive component for an intercalated graphite sample of cross-section 6 x 10^{-4} cm^2 at 40 MHz.) The apparent sample inductance for both types of fibers was found to be independent of frequency: fifteen percent below that expected for a solid conductor of equal cross-section and resistivity. It is hypothesized that, based on the earlier measurements at 100 kHz, greater dispersion of the filamentary conductors would result in significant reduction of impedance.

3. PUBLICATIONS

[1] "Remote and Distributed Electromagnetic Radiators," Valley Forge Research Center Quarterly Progress Report No. 28, 15 February 1979, pp. 37-63.

[2] "Remote and Distributed Electromagnetic Radiators," Valley Forge Research Center Quarterly Progress Report No. 29, 15 May 1979, pp. 25-63.

[3] "Remote and Distributed Electromagnetic Radiators," Valley Forge Research Center Quarterly Progress Report No. 30, 15 August 1979, pp. 15-44.

[4] F. Haber, "The Widely Dispersed Array in Tropospheric Scatter System," Valley Forge Research Center Quarterly Progress Report No. 30, 15 August 1979, pp. 63-69.

[5] "Remote and Distributed Electromagnetic Radiators," Valley Forge Research Center Quarterly Progress Report No. 31, 15 November 1979, pp. 12-24.

[6] J. Vespoli, F. Haber, R.S. Berkowitz, D. Yavuz, "A Self-organizing Random Array Communication Relay," Proceedings of the 22nd Midwest Symposium on Circuits and Systems, Philadelphia, Pennsylvania, June 1979, pp. 452-460.

[7] D. Yavuz, "Frequency Properties of Random Arrays," Proceedings of the 22nd Midwest Symposium on Circuits and Systems, Philadelphia, Pennsylvania, June 1979, pp. 461-465.

[8] D. Yavuz, "Frequency and Focal Region Properties of Random Array Relays," prepared for submission to IEEE Trans. on Communication.

[9] J. Vespoli, F. Haber, D. Yavuz, R.S. Berkowitz, "A Self-organizing Random Array Communication Relay," in preparation for submission to IEEE Trans. on Communications.

[10] N.H. Farhat, T.H. Chu, "Remoting of UHF and Microwave Radiators via Fiber Optic Links," in preparation for submission to Proceedings of IEEE, (correspondence).

4. SCIENTIFIC PERSONNEL

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5. Advanced Degrees

Jorge Benjamin Vespoli, "The Widely Distributed Random Array as a Radio Relay," Masters Thesis, June 1979.